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Some Physiological Factors in Stock Feeding

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SOME PHYSIOLOGICAL FACTORS IN STOCK FEEDING

. BY .

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Henry Disbro Scudder

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OF Bachelor of Science

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The last half century has indeed seen remarkable gains in our knowledge of the art of feeding livestock. Scientific investigation into the fundamental laws of rational feeding have been most actively and industriously carried on, and the theories of feeding farm animals have, from repeated proof of their truth, been firmly established on a scientific basis and the paths for their future progress plainly indicated. From mere theory, feeding has become an applied science and has its devoted experimentors and educators in every civilized land. To Germany especially is credit due for the untiring attention and persistent study given this subject. Such men as Liebig, Voit, Wolff, Pettenkofer, Lehman, Henneberg, Schultze, Kellner, Frankland, Soxhlet, Thaer, Kuhn, and numbers of other eminent German scientists, spent a large share of their lives in the advancement of this work. From Germany, Lawes and Gilbert, Fleming, Voelcker, and the Smiths, of England, and Boussingault, Dumas, Milne-Edwards, Persoz, Grandeau, and Leclerc, of France, received their inspiration and to all of them our own Henry, Jordan, Armsby, and the many other Experiment Station workers, are indebted for the solid foundation upon which to rear an ever-heightening super-structure.

Although the practical importance of the subject must not be forgotten, as the ultimate object of this branch of applied science is to enable one to feed better and more economically; still the writer of this short paper has endeavored, as far as possible, to comprehend in it our present knowledge of the unchanging natural laws, physiological rather than chemical, of the nutrition of farm animals, for the only sure and lasting foundation for a rational practice is a thorough knowledge of the natural laws on which it is based and with which it must be in accordance in order to be successful.

The science of feeding farm animals has long been studied in the chemist's laboratory, and that side of the question has been very fully developed, but the far more complex and intangible physiological processes are the points which have been neglected and against which science should mass its strongest forces. Hence, though the chemist's conclusions must necessarily form a factor in the consideration of the physiology of animal nutrition, still the latter will be the standpoint from which the present writer will approach the subject. With this in mind it will be endeavored to outline, as fully as possible in this brief review, the present extent of our knowledge and results; to indicate the processes by which this knowledge and these results have been

reached and the degree of truth which attaches to them; and, finally, to attempt, in a limited way, to point out the directions in which our knowledge is still deficient. Though investigation and experimentation in every phase of the physiology of animal nutrition have been carried on extensively by scientific men of eminence, both in this country and abroad, many results are far from complete or correct in their conclusions. Before the subject can be entered upon with intelligence, it is necessary to become thoroughly acquainted with the elements and compounds of animal nutrition, followed by studies of the digestion, resorption circulation, respiration and excretion, of the different domestic animals and all the conditions influencing them. The composition of the animal bodies, the proportions of the various tissues, the nitrogenous, non-nitrogenous and inorganic tissues - to each other, must be understood. These studies prepared for and led up to the main theme itself - the study of the function of the nutrients and their physiological value, of the laws of animal nutrition, of the sources and formation of flesh and of fat, and of the production of work, as well as of the different methods of investigation which have been used in the past and at present in the ascertaining of this knowledge.

In this study of animal nutrition, however, feeding standards (those German prescriptions "to be given according to directions"

have been somewhat largely ignored and purposely, owing partly to the fact that they belong more properly to the chemical side of the subject, and partly, that there has been an unwise tendency to center study of animal nutrition too closely around these feeding standards. Of course, there is no doubt that ration standards are helpful in working up uniform and adequate feeds for our animals, but still even in their best form they are only imperfect expressions of exceedingly variable and as yet little understood relations. No feeder will attain success who indiscriminatingly adheres to these "mathematical doses of nutrients" whose accuracy he allows to outweigh all other considerations and relieve him of exercising his judgment or his observance of fundamental principles in feeding. As one writer says, "Rational cattle-feeding is not to be attained through a blind acceptance of existing standard rations but by means of a broad understanding of the scientific and practical knowledge in which these standards had their rise."

Since the food is the source of the substance and energy of the animal body, it is next in order to ~~next~~ briefly consider how the nutrition of an animal is effected, how all the different food compounds are changed into available form and built up into the tissue structure and fluids of the body. This is accomplished by the two processes called digestion and assimilation.

Digestion is briefly a process of solution, a conversion of the solid food nutrients into forms which are soluble in water or in the digestive fluids and are then ready for diffusion and absorption into the circulation. The albuminoids are dissolved by the gastric juice in the stomach and the pancreatic juice in the intestines; the starch or carbohydrates by the saliva and pancreatic juice, and the fats by the bile and pancreatic juice. Digestion is then both a chemical and physical process. The feeding stuff is first masticated, finely divided mechanically, then acted upon by the various juices of the alimentary canal, which completely modify the form, the soluble, diffusible portion absorbed into the blood, the insoluble part rejected as the excrement or manure of the animal.

Assimilation follows digestion. It is not included in it, as is so often believed. It is the conveyance of the digested nutrients into the blood and the circulation and distribution of

these various nutrients by the blood through the tissues in which the building up of flesh and bone and the production of energy take place.

The ferments of the digestive fluids are perhaps the most important of all the agents of digestion. Ptyalin, the ferment in the mouth, in the saliva, is the first one to act on the food. Aside from moistening the food, the saliva changes the starch into sugar; thus the finer the division of the food by the teeth or by man's artifice, the more complete is this action. An enormous quantity of saliva is used, and by experiment by both Colin and Smith it is found that from 88 to 132 lbs. of saliva are daily secreted by the horse or steer.

In the gastric juice, the digestive fluid of the stomach, the chief ferment is the enzym, an unorganized ferment. Its main service is the conversion of the albuminoids of the food to peptones, which are so soluble and diffusible that they are readily absorbed as nutrients into the blood by the agency of absorbing vessels, the villi, which line the walls of the alimentary canal. Another prominent ferment in the gastric juice is rennin, which, together with free hydrochloric acid, also largely assistsin the digestion of protein. Pepsin, indeed, is unable

to act without the presence of this free acid.

In the intestines the food meets the bile and the pancreatic juice. The bile is chiefly valuable for its power of digesting the fats, for without its presence the fats pass out in the excrement undigested. The bile forms an emulsion of the fats, which are then readily passed into the blood. The pancreatic juice is the last fluid to act on the food. Just the reverse of the gastric juice, it requires an alkaline medium to act in. It contains three ferments: trypsin, which completes the proteid digestion by changing albuminoids to peptones; a diastatic ferment, which, with the intestinal juice, completes the digestion of the carbohydrates, the change of starch into sugar; another enzym., which completes the digestion of the fats.

Before closing this brief sketch of the digestion of the food nutrients, we must not neglect to say, that all through the alimentary canal a series of fermentations take place caused by numerous bacteria and giving rise to the foul gases of the feces, which have as their result the digestion of cellulose, the most indigestible content of animal foods. Cellulose constitutes a large proportion of the manure, and it is portions of the bile which escape resorption that give manure its color.

Assimilation is the absorption, or sometimes called the

resorption of the digested nutrients into the blood and their circulation and construction into the body tissues. This absorption takes place by the common physical process, osmosis, the diffusion of a heavy or dense liquid, the intestinal solution, chyle, into the light fluid, the blood, through the thin, intervening membrane, the intestinal walls. But there is considerable in this absorption of the chyle into the blood that is as yet little understood. As before stated, the albuminoids are converted into peptones and absorbed into the blood in that form; yet by the time the blood is reached by them they are no longer peptones. No such substance can be found in the blood. The change must occur during the process of absorption, but although this is a comparatively simple function no light has as yet been given as to how and where the change takes place. All the literature obtainable was looked into for explanation of this change but no knowledge on the question is shown. Further than that, in their passage through the tissues lining the digestive tract the peptones are converted into nearly their original form as albuminoids. The matter is a mystery yet to be solved. One scientist believes that there must be some vital forces contained in the living animal cells which serve some office in effecting this change while the nutrients are being

transferred from the intestinal tract into the blood.

Another author believes that the resorption of the digested nutrients does not take place through the process of diffusion of liquids, but that it is a function of the living protoplasm of the epithelial cells themselves which line the walls of the digestive tract. He gives some very reasonable proof to show that osmosis cannot take place. The transformation of the peptones might also take place in these epithelial cells.

The protein nutrients arriving then at the blood in the shape of peptones are converted into it in the form of serum albumen. This is carried through the blood vessels and capillaries in the body tissues, bathing and nourishing them, repairing the broken down tissue, or causing the division of the animal cells which constitute growth.

The fat nutrients are taken into the blood nearly unchanged and are built into the fatty tissues characteristic to each different animal. The carbohydrates are converted into sugar, as we have seen, which goes to form glycogen, stored energy, or is oxidized into carbonic acid and water, or may be changed into fatty tissue.

The nutritive processes of the animal body are really a series of oxidations by which the organic matter of the foods are

restored to inorganic matter. The income of the body is compounds of carbon, hydrogen, nitrogen and oxygen; the outgo is the same elements, as carbon dioxide, water and urea. The carbon and hydrogen of the food unite with the oxygen of the air and give these oxidation products. But oxidation is always accompanied by heat; thus we can account for the warmth of the animal body. Such processes of combustion, however, are seldom complete. The albumen, for instance, in the process of oxidation results in the formation of urea which can still further be oxidized. Thus we can find how much heat a certain nutrient leaves in the animal body, for, knowing, for example, the amount of heat an ounce of albumen would give off in oxidation and knowing the amount a proportionate weight of urea would give, we could make a subtraction and the difference would be what is left in the body. Thus, by experiment, it could be found how much heat any of the food nutrients would leave in the body and thus food stuffs could be compared in value to each other by the amount of heat they would leave in the body in oxidation. This retained heat is what constitutes what is called the heat co-efficient of a food stuff. Many scientists, however, put too much confidence in this heat co-efficient matter. They forget that the energy produced by the oxidation may also take the form

of mechanical work, the movements of the muscles, the radiation, and the evaporation from the skin of the animal. The proportion of surface to weight indeed cuts a large figure, small animals freeing relatively more heat than large animals.

By the absorption from the alimentary canal the blood is, then, constantly receiving additions. By the excretions and secretions, and by the repairing and building up of the body tissue, the blood is constantly losing portions of its constituents. The balance between this income and outgo of the blood is what constitutes nutrition. If the income exceeds the outgo, the animal increases in weight; if the reverse takes place, the animal loses weight.

In studying how this nutritive equilibrium is maintained, it is seen that the income of the blood consists of compounds of carbon, hydrogen, oxygen and nitrogen; the waste products being carbon dioxide, water, urea and salts. The nitrogen is removed from the body in the urea, the carbon in the carbon dioxide of the lungs and skin, the hydrogen in the water, and the oxygen in the form of water and carbon dioxide. But the attempt to trace a nutrient from its ingestion through all the different steps to its excrement as waste is a very difficult, and, in some cases, an impossible thing to do. This is a place at which scientific

students of the animal physiology seem to have accomplished almost nothing in ~~its~~ elucidation.

To trace the serum-albumen of the blood to its final product, the urea, is very difficult. It has been proved by numerous experimentors that the amount of urea varies with the amount of albuminous destruction going on in the body, also that the amount of urea varies in proportion to the amount of nitrogen consumed, but that is where definite knowledge ceases. It is believed, however, that on muscular exertion the albuminous tissue breaks down into kreatin and this substance increases as the work increases. The relation of it to urea is not clear, however. Where kreatin is converted into urea is not known.

The decomposition of albuminous matter in the intestines may be another possible source of urea. Large amounts of protein in the alimentary canal increase the amount of urea eliminated. The excess protein in the canal breaks down into leucin, and it is found that leucin introduced in the alimentary tract increases the urea. Uric acid may also be a source of urea.

The fat of the food is absorbed into the blood supply largely unchanged and since the fatty or adipose tissue varies most rapidly and widely the fats can be more easily followed

through the body. Liebig first proposed and Lawes and Gilbert long ago proved beyond the shadow of a doubt that the fatty tissue of the body may not only have its source in the fat of the food but must be derived from the carbohydrates, partially, as more fatty tissue is constantly found in the animal body than the fat of the food could possibly supply. The proteids also are a source of animal fat, as is proved by the fact that animals fed on lean meat will deposit considerably more fat in the body than is contained in the food. Fatty degeneration of muscle is also due to the breaking down of the proteids into fat, while fatty acids may easily be developed in the pancreatic digestion of protein.

Several later investigators conclude from their researches that the fat formed from the albuminoids unites much more readily with oxygen, that is, burns easier, than the ready formed fat taken from the food, although no definite reason for this could be found in their writings.

Although both these sources of fat were strongly argued against some years ago, we now have numbers of experiments which prove their truth. The fat is largely broken down in the expenditure of energy and oxidized as carbon dioxide in the lungs and from the skin.

The carbohydrates of the food enter the blood as sugar, as has been shown, and are either rapidly oxidized as CO_2 or H_2O, passing off from the lungs or skin, or are stored up in the liver as glycogen or go to make fat directly or indirectly by sparing a certain amount of albumen from destructive oxidation. The oxidation of the carbohydrates takes place mainly in the muscles, as is proved by the shortness of breath caused by hard muscular effort, which is necessary to get rid of the large amounts of the oxidation product, carbon dioxide. The liver acts as a storehouse for immense amounts of carbohydrates, in the form of glycogen, for the blood will not contain sugar but eliminates it through the kidneys, if present. This glycogen is largest in amount when the animal is in the highest state of nutrition, for it is reconverted into sugar and oxidized when there is a call for energy expenditure.

As to the source of force in the food, or reviewing all the results of experiment as to the characteristic food requirements for the exercise of force, the evidence is cumulative and decisive that with normal food and moderately hard work no increased demand for the nitrogenous food constituents is shown, while the need for the more especially respiratory constituents,

that is carbohydrates and fat, is always largely in proportion with the force expended. If labor is abnormally heavy, pushed to the point of the entire dilapidation of tissues, as indicated by weight loss, there will be a degradation of nitrogenous matter and increased nitrogen elimination in the urine, giving rise to an increased demand for nitrogenous food substance. But for moderately hard work it is certainly a fundamental fact that the non-nitrogenous constituents of the food are largely the source of muscular power. Though it was formerly thought that muscular effort was sustained at the expense of muscular tissue, this was disproved by the two scientists who climbed a mountain, excreting no more urea than when they were much less active. Numerous other accurate experiments have shown the truth of this. It has also been found than when work increases, the excretion of carbon dioxide increases in like proportion with but slight increase in the protein excretion. The experiments of Dr. Edward Smith on pigs showed that the CO_2 exhaled varied from 19.2 grams per hour in sleep to 189.2 grams in working a tread mill. At the same time he conducted experiments on the elimination of urea with different conditions of food and exercise for a period of more than two years, which resulted in showing that the urea eliminated from the system varied in

direct proportion with the consumption of nitrogen by the animal, there being but very little variation in urea with great variation in labor performed. Zuntz and Lehman, in experimenting with the horse, found that the CO_2 exhalation was, while the animal worked, six times that while at rest, with a great and immediate reduction in exhalation as soon as work stopped. These and many other experiments examined confirm the fact that with muscular exertion there is a marked increase in demand for non-nitrogenous food and little, if any, increased demand for the nitrogenous constituents. Everyday experience approves this conclusion. Horses, with which we do the severest kind of labor daily, we seldom give any other ration but corn and hay.

For the production of milk the drain on the food is even greater than in the production of flesh, especially in nitrogenous substances; and if, as is frequently assumed, the butter fat comes largely from the protein of the food, the drain would be much heavier, as it would take two parts or more of the nitrogenous substance to make one part of fat.

A maintenance ration is one which just accomodates the animal without loss or gain while it is at rest just enough to create energy sufficient to carry on the internal bodily activities. But herein lies a point that is often neglected by

experimentors in calculating the increased work equivalent obtained by a given increase in the food consumption. The moment external work is added to the animal at rest, the consumption is increased, but this increase is not all to be figured to the external work evidenced, for with the increase in rations, the activity of the internal physiological functions are greatly increased and thus the maintenance ration is increased; thus the original maintenance ration of the animal while at rest if subtracted from the increased ration would not give the fair equivalent of the increased consumption in work produced.

Now, although all these chemical and physical changes in the food nutrition which take place in the digestive organs are largely beyond our control, there are many ways of handling and feeding the foods, which are within the power of the feeder, which will greatly influence their future conduct in the digestive processes.

No more space can be taken in this paper, however, than but to briefly mention the results of the many valuable experiments which have been carried on all over the country. The many different methods of preparing food for animals, such as wetting, steaming, fermenting and cooking, are now rapidly going into disuse. It was believed that these preparations aided in more complete digestion, but many experiments have shown that this is a popular fallacy; that the improvement in all cases is not sufficient to pay for the expense and labor involved. If there is any value in these treatments, it is yet to be proved. Cooking of food indeed diminishes the digestibility of the protein in nearly all cases, and unless it makes a food considerably more palatable, thereby increasing the consumption, it should not be done.

Palatability is indeed an important factor in successful feeding, for the digestive juices are under the control of the

nerves very largely and as the appetite is a nervous habit any tempting food mixture the feeder can prepare to stimulate it, by agreeable flavors and odors, is an advantage.

The appetite of the animal indeed is a thing more attention should be given by many feeders. In animals where money is no object, such as in breeding or show animals, where the sole object is perfection regardless of cost, the appetite may well be catered to, and in the case of the show animal, even tickled to tempt the animal to eat more and lay on every ounce of fat possible. In breeding stock, though the appetite can be catered to to a considerable extent to give the fullest growth and vigor, it should not be done so far as to cause harm to the sexual strength. In stock raised for market of course the appetite must be differently treated. The region surrounding the feeding location, owing to the nature of the climate or soil, may furnish certain crops most cheaply, and thus our stock must be trained to like this crop or mill by-product. And this can be done by gradually adding it to their ration in increasing quantity. Gluten meal, for example, is often refused by stock, but necessity soon teaches them to like it. Of course, sufficient variety must be given animals to avoid cloying the appetite, as this would be a serious set-back in any feeding operation.

Drying fodders or curing them has long been believed to diminish their digestibility, but unless this is improperly done, or unless large amounts of the finer leaves are broken off in handling, curing fodders is not injurious to them.

The maturity or ripeness of grain and fodder when harvested affects their digestibility considerably. The older the grasses become after having bloomed, the less is their content of digestible nutrients and the greater the amount of cellulose. With the grains, as a rule, the longer they ripen, the better they are.

As to the grinding of grain, numbers of experiments have been tried, and although there are some conflictions, the general conclusion is that the digestibility of nutrients is increased sometimes as much as 10%. In many cases, however, this increase does not pay for the labor and expense of the grinding and therefore is not profitable. The advantages of the chopping, shredding and siloing of the coarser fodders are too well known to need repetition here.

As to the influence of the quantity of a ration on its digestibility, Wolff believed that, whether taken in large or small amounts, the nutrients were just as well digested. Many experiments since that have shown that digestibility decreases slightly with increase in amount, especially in the straws and

like coarse fodders. Neither over nor under feeding should be practiced, however. More evidence is desirable on this point.

As to the value of salts in the animal nutrition, there is much to say on that question. Liebig first recognized the importance of the mineral salts found in the animal body, especially Na., Cl., K., Fe., Ca., Mg., and P_2O_5 being essential to the health of the animal. In earlier times it was thought, with the exception of the lime salts in the bones, that these inorganic substances were of little value, or even accidental. It has been shown by experiment, however, that their absence in food causes death very soon, even if the animals have an abundance of organic food. The case of the pigs fed with corn meal alone, by Lawes and Gilbert, showed sickness increasing with the animals, owing to the low mineral salt content of the corn, which was at once relieved when they were fed a mineral mixture of different salts. The value of common salt has already been mentioned in this paper.

Another point on which but a few (and those valueless) experiments have been performed is the frequency of feeding and watering, which assist the digestive processes most advantageously. These two points, and that of the amount to feed our animals, have not, as yet, been sufficiently developed. We do

not know how often or how much to feed to secure the best results.

The length of time intervening between the daily feeding of farm animals is a matter of considerable importance. If animals are fed too often, the digestive organs are given no rest. The ruminants should not be fed too often, as they require lots of time to ruminate their food properly. Two or three meals a day are sufficient. Horses and hogs, owing to their smaller stomachs, should be fed often, three to four times daily. In young cattle, owing to the relative small size of their stomachs, four to six feeds should be given. Too long intervals between feeds tend to produce poor mastication and improper insalivation on account of the great hunger and consequent haste in eating. In the horse and pig this latter error leads often to very serious trouble.

The low digestibility of the coarse fodders is especially noticeable in the horse. Owing to its small stomach and its less perfect mastication, much less of the crude fibers of hay and like fodders are digested by the horse than by the sheep and steer, although the statement is commonly made that the digestion is almost the same. For concentrated foods digestion is the same, or even better, in the horse and hog than in the ruminants. The matter of breed difference does not affect digestibility.

There is no doubt, then, that bulky, coarse fodders are the natural foods for which the ruminating animals are fitted. One experimentor, however, Miller, showed that rumination could be suspended for a considerable time without injurious results. He developed a system of feeding cows during the winter on corn meal exclusively, three quarts per day per head, and although, of course, the rumination was entirely suspended for some months, no bad effects were discovered. Others tried the same method and succeeded. The opinion has long been universally held that a certain amount of bulk is essential to the ruminating animal, but this does not seem to hold true in all cases.

The relative proportions of the different classes of nutrients in the ration also exercises a perceptible influence on digestibility. The excess, for example, of carbohydrates in a ration cuts down the total digestibility to a considerable extent, the digestion of the protein and fiber constituents being especially depressed. Investigation has not been decisive enough, however, to lead to a definito and correct conclusion.

From comparison of the tables of composition of steers, sheep and hogs, as analyzed by Lawes and Gilbert, and then from observations of the tables of amounts of increase in flesh for a given amount of feed in the different animals,it appears that steers, while their food is the most bulky and in proportion least nutritious, yet they have the largest proportion of stomach and least of intestinal surface for the absorption of nutriment, and give also the least degree of increase for a given amount of dry matter of food. In these respects sheep come next to oxen, while the dry substance of the food of the pig is in much the greatest degree digestible and available for assimilation and respiration. He yields also much the most increase for a given amount of dry food,due largely to the fact that he has by far the largest proportion of intestinal surface for the absorption of nutritious matter. By calculation from these tables steers expend in respiration the most of the dry substance of food in proportion to a given amount of fattening increase yielded, while sheep expend less and, strange to say, hogs the least.

From the general results of this experiment in fatting pigs, sheep and steers,under cover, a comparison shows that pigs should yield per week about 5 or 6% of their weight in increase, sheep 1.7% and steers 1%.

The same amount of live weight for the same time, of sheep will consume 1.2 times, of pig 2.2 times, as much dry substance of their food, as steers.

Again, the pig requires only 4 to 5 lbs. of the dry substance of its food, the sheep 9 lbs., and the steer 12 to 13 lbs. to produce 1 lb. of increase. These results show quite conclusively, then, that as a machine for transforming stock food into flesh with the greatest rapidity and economy, the pig ranks far ahead of all the other farm animals.

We know that the animal is a direct product of food, and thus we should expect to find his body composed of the same material and so it is. The food is divided into the nitrogenous, non-nitrogenous and inorganic classes of constituents and the animal composition is divided into the same parts, only in entirely different proportions to each other. Lawes and Gilbert have done the most extensive work on this point, having slaughtered and analyzed ten animals of different kinds and conditions. The Maine Station also did the same with four animals. Some of the results of these experiments will be given below.

Of total nitrogenous compounds, as well as of total mineral matter, oxen seem to contain, under parallel conditions, a rather higher percentage than sheep, and sheep rather more than

pigs. Thus the entire body of a fat calf contained about 15-1/4% of nitrogenous substance, that of a moderately fat ox 14-1/2%, of a fat lamb 12-1/3%, of a fat sheep 12-1/2%, of a very fat sheep about 11%, and of a moderately fat pig about 11%. Lean animals contained from 2 to 3% more than moderately fat ones.

On the other hand, fat constitutes by far the largest item in the solids of the entire bodies of animals, especially those suitable for slaughtering as human food. Even the half-fat ox contained about 19% of fat, more than that of nitrogenous substance. The entire body of the lean sheep contained nearly 19% of fat, several per cent more than the nitrogenous substance; that of the half-fat old sheep and that of the lean pig more than 23% of fat, in the former 1-1/2 and in the latter case 1-2/3 times as much as the nitrogenous substance.

Of the fattened animals, the entire body of the fat ox and fat lamb contained about 30% of fat; that of the fat sheep 35-1/2% and of the very fat sheep 45-3/4%, and that of the fat pig about 42%. The fat calf, however, contained even less than 15%.

Hence the entire bodies of lean animals may contain more fat than nitrogenous substance, while those of fattened animals may contain several times as much. That of the fat ox contained

more than twice as much, of the moderately fat sheep nearly three times as much, of the very fat sheep more than four times as much, and of the moderately fat pig about four times as much.

Both in the carcasses and in the entire bodies, there is a marked decrease in the per cent of mineral matter as the animal matures. Judging from the results of analyses of animal bodies, about 40% of the mineral matter is phosphoric acid. Lime constitutes nearly 45% of it, in the case of oxen and sheep, and about 40% in pigs, while of potash there will probably be about 5 or 6 per cent in the ash of oxen and sheep, and 7 to 8%, or more, in that of pigs.

As to the relative proportion of the food constituents and the composition of the increase of the different animals analyzed, Lawes and Gilbert also give some valuable data.

The increase of liberally fed oxen, during the last six months or more of fattening, will probably consist of 70 to 75% solids, of which 60 to 65% will be fat, 7 to 8% nitrogenous compounds, and about 1-1/2 mineral matter.

The increase of liberally fed sheep, during the last five or six months of fattening, will probably consist of 75%, or more, of solids, of which 65 to 70% will be fat, 7 to 8% nitrogenous, and about 1-3/4% mineral.

The increase of pigs fed for fresh pork production, during the last two or three months of fattening food, will probably consist of 67-1/2% to 72-1/2% solids, composed of 60 to 65% of fat, 6-1/2 to 8% nitrogenous, and considerably less than 1% mineral. Of pigs fed for curing, the increase in the last few months of high feeding will show considerably higher percentages of fat and total solids and less of nitrogenous and mineral constituents, than in more moderately fattened animals.

Lawes and Gilbert persistently claim that the theory advanced by so many scientists, that the various fattening foods are valuable in proportion to their percentage of nitrogenous compounds, is fallacious and their many experiments give them strong support in this assertion. No doubt that most scientists, when they take into consideration the immense importance of the functions exercised by the nitrogenous tissues and fluids of the body, are inclined to conclude that the richer a food in protein, the higher its value. But Lawes and Gilbrt, after looking back on years of experiment, still adhere to their original statement which contradicts emphatically that given above and with considerable show of reason.

Since the solid increase of fattening animals is very largely fat itself; since a great part, at least, of the stored-up fat

is probably derived from starch and other non-nitrogenous constituents of the food; since the respiratory demands of the system require so large an amount of non-nitrogenous constituents; and since the current fattening foods contain very much more nitrogen than is eventually used in the increase, - it is evident that the comparative value of foods, as foods, does not depend on their percentage of nitrogenous compounds. If the amount of nitrogenous compounds in the food be not actually deficient - which is seldom the case - it is practically true that the amount of increase much more frequently depends on the proportion of digestible and assimilable non-nitrogenous compounds than in that of the nitrogenous ones.

A study of the food of those laboring classes who are under- rather than over-fed will show that their first desire is for fat meat, such as pork, rather than the leaner and more nitrogenous, apparently responding to an instinctive call for an increase in the respiratory constituents of their food. The higher classes undoubtedly consume a larger proportion of leaner meats, but they also consume a larger quantity of butter and sugar, and probably more fat than is generally imagined, fat and butter having about twice and a half the respiratory capacity of starch. It is worthy of note that prepared staple foods are

generally concentrations of non-nitrogenous or respiratory constituents. Sugar, butter and alcoholic drinks are good examples of this. Cheese is only an apparent exception, since that containing the most butter, costs the most, and butter itself always costs more than cheese.

We must not depreciate the value of even a somewhat liberal amount of nitrogen in food. It would seem, nevertheless, that too high a relative importance has been attached to it, and that it would conduce to progress if current views on this subject were modified to some extent.

As the manure from highly nitrogenous foods is the most valuable, it may at times be most profitable ~~to use foods~~ to use foods of this character.

The comparative values of food stuffs, as such, are not to be unconditionally determined by their percentage of total nitrogenous and non-nitrogenous constituents. Possessing the numerous valuable records of ultimate analyses of foods, the desideratum now is to examine more closely into the nature and condition of their proximate compounds - to distinguish those which are digestible and assimilable from those which are not - to determine the relative values of comparable or mutually replaceable portions, - and above all to fix our standards of

relative value with closer reference to direct experimental evidence and the existing knowledge of the composition of animals, than has previously been customary, or even possible.

In regard to condimental feeding, of which one so often reads in the advertising columns of the agricultural journals, and concerning which one so frequently hears inquiry or complaint of, in the more uneducated class of farmers, several investigations have been entered into which are conclusive in their evidence. Voelcker of the Woburn Experimental Farm, England, fed a number of bullocks with molasses and condimental spices and showed that there was no virtue in them, that the bullocks fatten just as well and as economically on a well chosen mixture of ordinary foods. Nor did the use of condiments enable the bullocks to consume more of the bulky foods, such as straw and hay chaff. Molasses caused a tendency to "looseness", so, very little of it could be fed, and the spices did not bring as good returns even as the molasses.

Sir John Lawes also inquired into the matter of condimental feeds and relates as a parallel the amusing incident of the Waterloo Caesarian cow-cabbage, introduced years ago in England, "of which it was said that two or three plants would be sufficient to keep a flock of sheep through a whole winter, and that the stems were so large as to be suitable for the rafters of buildings. As it was evident that one year's trial would settle the

merits of the cabbage, it was necessary to exercise considerable ingenuity in its introduction. It was said that only a few of the seeds were in existence which might be purchased of a tailor in St. James Street, in packets of 21, for the small sum of one guinea. Of course, numbers of persons were anxious to secure one of the few packets, which, it is needless to remark, were always found equal to the demand. The result in the following summer was a general laugh at the expense of the purchasers." Lawes claims the condimental feeds just as disproportionate in value to their cost as the cow-cabbage, and showed it was just as easy to determine whether the daily use of an ounce or two of condiment would cause a pig to fatten "in half the usual time" as whether a cabbage would grow as big as a barn. The experiment proved how decided the loss to the feeder using expensive condimental foods, and how untrue "the assumption that the use of the so-called condiments increases the assimilation of food by fattening animals in healthy condition." Lawes admits that perhaps in the case of old, over-worked, debilitated horses, or fattening animals of poor constitution and weak digestive power, condiments might happen to be of some good, but even there they could be better replaced by ordinary medicine or treatment.

If the coloring with "turmeric, and flavoring with cumin, anise or other of the stimulating and carminative seeds used in cattle medicine" were left out of most of these manufactured foods, an equally nutritious feed could be made by mixing linseed meal, cottonseed meal or other of the concentrated nitrogenous feeds, and at about one-fourth the cost. The cost of manufacture in obtaining nutrients in their pure state, such as starch, sugar, etc., is so great that there is no possibility of their replacing the same nutrients as found in oilcake, oats, corn, etc. Neither will any degree of concentration of food constituents, nor any amount of particular ones, enable the animal to obtain a particle of what is necessary to nourish his system from any other source than his food.

While speaking of special foods it might be well to dwell a moment on the need of salt for farm animals. Besides its strictly physiological functions, it is of great value in assisting the passage of the abuminoids from the digestive tract into the blood, and of facilitating the circulation of the blood, and thus increasing the activity of the vital processes. An excess of salt seems to be necessary to do this, which circulates rapidly through the body and is excreted in the urine in proportion to the amount taken in. Those of our domestic animals

that are largely stall fed, and with abundant fodder, are caused to produce either flesh, fat, milk or work, are especially in need of salt, for many of the fodders in common use, such as roots, stover, etc., are deficient in sodium chloride and rich in potash salts, which latter cause an increased excretion of salt in the urine. From the advantages of a certain excess of salt, then, it should be regarded as a necessity rather than a luxury. It has been shown by experiments by Weiske, Hofmeister and confirmed by Wolff, that too much salt is injurious rather than beneficial, as it slightly diminishes the digestibility of nutrients. Besides increasing the protein consumption, salt stimulates the appetite. From the fact that salt increases the excretion of urine, if an animal is prevented from drinking water and is fed salt, the water which would have otherwise passed off through the lungs and skin is diverted to the kidneys, and lacking supply is drawn from the body tissues. Thus an animal can have its live weight shrunk very rapidly, which by giving water again can be very rapidly increased again.

In this connection, Lawes and Gilbert found in an experiment in feeding pigs pure corn meal alone, that the animals soon developed large swellings on the neck, making swallowing and breathing difficult, and this proved due to the low mineral content of the

food, for when fed a mineral mixture of coal ashes, common salt, and superphosphate of lime, the animals soon recovered and turned out the best carcasses in the lot.

Just as feeding salt increases the excretion of urine and thus increases the demand of the system for water, so does the feeding of nitrogenous foods increase the amount of urea excreted, increasing the demand for water by the animal. This fact has been proved by experiments by Lawes and Gilbert, as well as many others. Thus it follows that the reverse is true; if animals drink large quantities of water, the protein consumption is increased, thus an increased consumption of valuable feed constituents, especially if the water is not retained in the tissues to a large extent but passed off as urine. Henneberg increased the protein ~~the protein~~ consumption of some oxen, 5.8% by increasing their water supply 22.4%, while Voit with fasting animals increased the protein consumption 25% by the same means. Thus protein which otherwise might have been deposited in the body was lost, so in order to get the best results in feeding either young or fattening animals, everything which leads to excessive consumption of water, too high a temperature, too much salt, too much movement or too watery fodder, etc., should be avoided as far as possible. For milk producing animals water seems to be bene-

ficial rather than otherwise, when freely inbibed, but excess is not advisable. One writer goes so far as to say that for a normal animal, four pounds of water to every pound of the dry matter of fodder for cattle would be a fair amount, and only about half as much for sheep, as they need less water in proportion to the dry matter than cattle. And this amount of water should not seem large when we remember that blood is four-fifths water, and water forms 42 to 67% of the weight of the whole animal body, varying with the species and condition, of course. The Maine Experiment Station analyzed the entire bodies of four animals and the Rothamsted investigators more than thirty, and these two independent experiments entirely agreed as to the water content in their composition. It was found that, strange to say, the lean animals contained a higher per cent of water than the fatted ones, showing that the increase produced in fattening has a far smaller percentage of water than the original lean fleshed body. The Rothamsted experiments found 40 to 48% of the increase to be water; the Maine Station, 42 to 58% of water, the higher percent being in the bodies of the younger steers. This difference between the young and the maturer beef accounts for the fact that the poor man prefers the older meat and the fatter meat, because it "goes further", it has a lower water content and he isn't

paying for so much water.

Excessive water drinking also has a bad effect on fattening animals, as it is a tax on the system to pass it off and thus retards fat formation. The dilution of the gastric juice by large quantities of water, and at too high or low a temperature, may suspend digestion by entirely destroying the pepsin and new pepsin must be secreted before digestion can proceed. Thus it is well to water animals before feeding and this will, as well, prevent the washing of any of the food out of the digestive tracts before it is properly fit. Indeed, watering at will has been found perhaps the best way of proceeding, if the other way cannot be properly observed. Backhaus found a decided increase in milk production in so doing in an experiment with stabled cows. Particular attention should be given to the horse in the matter of water. Its demands vary more than any other farm animal due to its large variation in employment. Horses at hard labor pass off excessive quantities of water and owing to their small stomach capacity should therefore be frequently watered.

In connection with this giving off of water from the skin of horses while at hard work, Professor Smith of Aldershot, derived some very interesting information by analyzing the sweat taken from a straining animal. He found considerable ammonia

and albumen contained in it and after making many analysis he calculates that by clipping heavy laboring horses,and thus reducing considerably their sweating, enough nutriment would be saved,to equal the value in feeding of a pound of corn daily. That seems a rather far fetched conclusion, but though it is only a small matter it counts and would certainly give the animal a perceptibly greater degree of comfort, and on that account alone is to be recommended.

The preceding pages have, then, attempted to examine into the extent of our knowledge as to the physiological processes of nutrition in farm animals; the digestion, resorption, circulation, respiration and excretion, and the conditions influencing them; to test the truth of this knowledge and show where it is deficient; to explain the composition of the different animal bodies, the proportion of the different tissues; and to seek the source of these tissues and follow them from their origination to their destruction; and thus, lastly, to arrive at an understanding of the function and physiological value of the different nutrients and of the laws of animal nutrition.

Even this brief study of animal nutrition, and that only from the physiological side largely, leads us to see strongly how great the need of a wider knowledge of the subject both for purely

scientific or purely economic reasons.

The elimination of the many doubtful points, such as, for example, the explanation of the manner and place of conversion of the peptones of the chyle into the serum-albumen of the blood, or the tracing of the intermediate steps of the albumen of the blood to its final form as excreted urea, can only be accomplished by the closest possible study and research into the physiological processes of animal nutrition.

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